SD421
Z5

FOREST FIRE DETECTION

LIBRARY
JAN 17 1969
ROCKY MOUNTAIN STATION

FOREST SERVICE
U. S. DEPARTMENT OF AGRICULTURE

The essence of this publication is change. Fire Detection, like so many other activities today, requires a heads-up, forward-looking attitude by resource managers. This is not optional, we have no alternative.

Business as usual is not the pattern of today or tomorrow. Someone has said that "the advancing waves of other people's progress sweep over the unchanging man and wash him out." Agencies and men who take their stewardship of the forests and related resources seriously cannot let that happen to them.

Edward P. Cliff

Edward P. Cliff
Chief, Forest Service

Issued January 1969

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 - Price 35 cents

SD421
.25

CONTENTS

	Page
Foreword	IV
I. The History of Fire Detection in the United States	1
The Evolution of the Lookout Tower	5
The History of Aircraft Use for Fire Detection	7
II. Current Trends in Forest Fire Detection	8
The Advancement of Aerial Detection	8
Some Considerations of Aerial Detection	8
The Air-Ground Detection System	10
III. Advantages and Disadvantages of Specific Detection Systems	11
Lookout Towers	11
Air Patrol	12
Air-Ground Detection	13
IV. Planning a Detection System	15
Basic Considerations	15
Planning an Air-Ground Detection System	17
V. Budgeting and Cost Factors	18
VI. Modern Technology in Forest Fire Detection	22
Bibliography	25

Use of trade names is for information purposes and does not imply endorsement by the U.S. Department of Agriculture.

FOREWORD

Forest fire detection techniques in the United States are changing rapidly. State and Federal agencies responsible for forest fire protection are studying and adopting new methods and are analyzing historical data on fire detection accomplishments and costs in light of changing conditions and values of the forest.

Aircraft are being more widely used for fire detection than ever before. This trend will continue as aircraft and airborne equipment developed specifically for fire detection come into use. On the other hand, fixed detection networks—such as lookout towers—are becoming less widely used as an exclusive detection system. They are proving to be increasingly expensive to operate and maintain because of higher costs of labor, materials, training, and administration.

The use of airborne remote sensing devices signals the first promising new operational concept in locating fires since air patrol was introduced around 1920. This new capability has great significance because, for the first time, agencies charged with fire detection are able to overcome many problems, including the increasing amounts of atmospheric impurities which have made detection much more difficult in many areas. New equipment and techniques permit the detection and surveillance of fires despite darkness, clouds, smoke, or other factors that limit visibility by conventional means.

This publication is intended to assist fire-control officers and planners in their efforts to obtain maximum efficiency at the least cost in their protection programs.

E. M. Bacon,
Deputy Chief,
State and Private Forestry.
Forest Service

FOREST FIRE DETECTION

By Eliot W. Zimmerman

Division of Cooperative Forest Fire Control

CHAPTER I

THE HISTORY OF FIRE DETECTION IN THE UNITED STATES

The first forest fire detection in America was carried on by the Indians and the colonial settlers. Their motivation was self-preservation rather than fire control. They had to know where the fires were, and the direction they were headed, so they could back-fire or plan to move out of the path of the fire. There were frequent threats to life and property from wildfire, and the sentiment among the early settlers was favorable to forest protection.

In Massachusetts, early laws provided for the care and protection of forests adjacent to communities. In New Jersey, laws against forest fires were also written early. Respect for forests acquired by their ancestors in England carried over to the protection of the forests in America. However, this attitude was short-lived. A growing realization of the vast forest resources at their command, together with the bitter struggle of the frontier farmer against the forest for his livelihood, eventually eliminated all desire to protect the forests. This feeling, brought about by the battle against the forest for livelihood, began to take a dominant place in the minds of the people and to create a mental attitude which was responsible for much of the forest destruction which continued undiminished for many years.

In 1899, Gifford Pinchot wrote *The Progress of Forestry in the United States* in the U.S. Department of Agriculture Yearbook. He made this statement on the forest protection of that day:

> Practical forestry has not yet been introduced on any State forest land and even New York, which owns about 1,250,000 acres in the Adirondack and Catskill Mountains, has not yet progressed beyond the stage of simple protection.

About the turn of the century there was some recognition that a successful forestry program would be dependent upon adequate protection from fire. Fire protection was then carried out on a very limited basis and was, for the most part, fully the responsibility of the individual property owner. The most common method of detection and control during this period was through an organized fire patrol. (See figs. 1, 2, 3, 4, 5, and 7.)

In the year 1900, some lumber companies began patrol operations which consisted, primarily, of men following every train during the dry season to extinguish fires that might be set by the locomotive. Other companies hired what they referred to as "rangers" during the dry seasons to patrol the forests, watch campers, and in case of fires, suppress them at once.

Figure 1.—Forest patrolman locating forest fire from lookout point. Montana, 1909.

F. 59299

This system is well illustrated by a statement made by a lumberman in Forest County, Pa.:

> In dry times, we patrol especially exposed areas. In spring and autumn during dry weather our woodsmen all have orders, no matter what they are doing, whenever they see a smoke arise, to go to it and put out the fire. It is usually done by back-firing entirely around and watching it until we are sure the fire is out. By this means we have kept serious fires from our timber when we are working. It costs us a few hundred to a thousand dollars annually. Usually successful, but not always.

During the period of 1900 through 1910, a few States were making some effort to protect the State and privately owned forest lands from fire. At this time, the state forestry organizations were very poorly financed and, as a consequence, were largely ineffective. New York and Pennsylvania were leaders in the State forestry program. Although 25 States had forestry organizations of some kind in 1911, their functions were mainly to gather information and give advice to private woodland owners. Financial support was meager and progress extremely slow. Only 16 States had forest fire protection organizations which were headed by either a State forester or a chief fire warden.

The total area of State and private forest lands then being given some measure of protection was estimated at about 60 million acres. However, the "protection" given to these forest lands was superficial indeed. The measures taken at that time would not be considered today to be protection in any sense of the word.

During this first decade of the 20th century, the best forest fire protection job on an extensive scale was being performed by a few private protection associations, mainly in the Northwestern States. There, some of the larger timber landowners had pooled their individual fire-control activities and had organized so-called protective associations to carry on fire patrol and firefighting for all of their members. Each member paid his share of the cost according to the acreage he owned.

At about this time, several smaller private protective associations were being organized in the Northeastern States, but, in general, they only collected assessments from their members and turned the funds over to the State forestry department which handled the protection work. The New Hampshire Timberland Owners Association formed in 1910 is believed to be the first association in the East which followed the Western pattern of maintaining a protection organization directly.

F–18264.A

Figure 2.—Maxwell runabout on fire patrol in California, 1913.

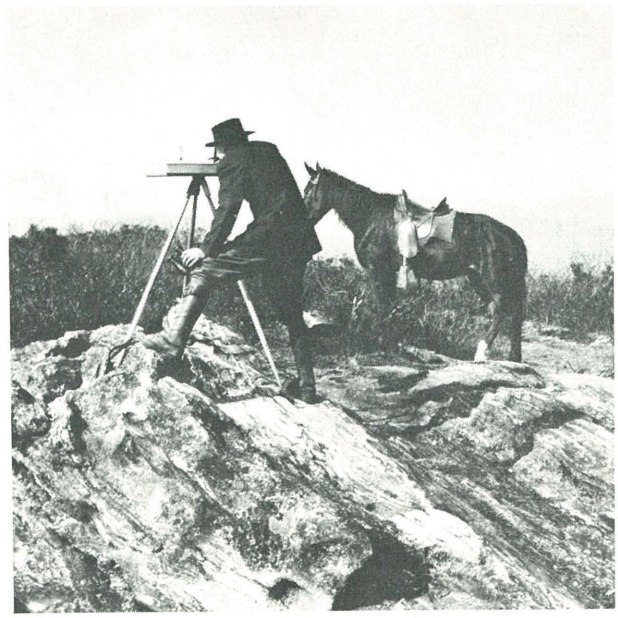
The disastrous 1910 forest fires in the Northwestern States, especially in north Idaho, stimulated the organization of additional private protection associations and also strengthened those which had been recently organized. Among them were the Northern Montana Asso-

F–18263.A

Figure 3.—Ranger in 20 horsepower Ford roadster fitted with flanged wheels, California, 1913.

F—176440

Figure 4.—Fire patrol guard on "leg-power" speeder, North Carolina, 1923.

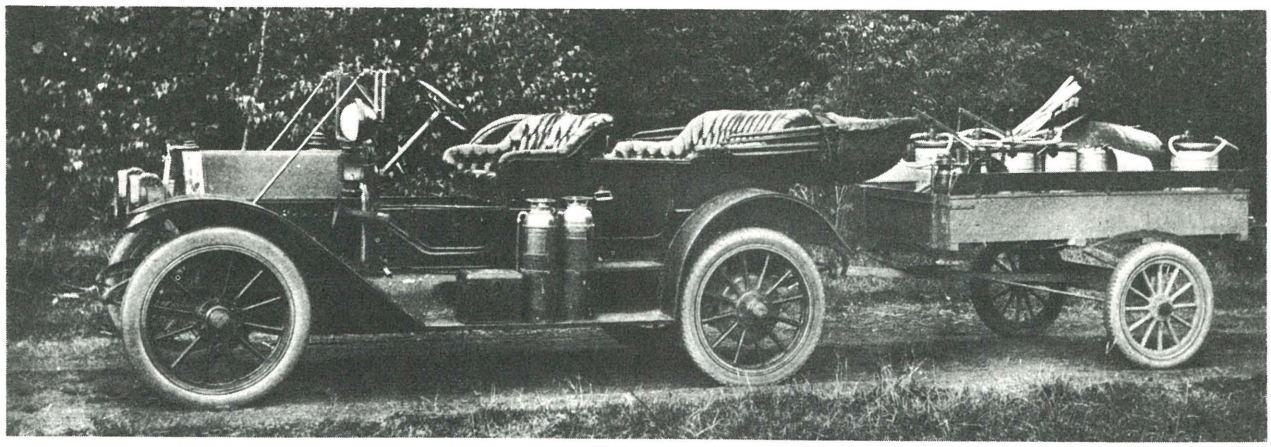


F—27296A

Figure 5.—Lookout spotting a forest fire from Satula Mountain, N.C., 1916.

F—42459A

Figure 6.—Combination living quarters and fire observatory at Hunter Peak, Wyo., 1918.



Courtesy of Massachusetts Div. of Forests and Parks

Figure 7.—Massachusetts Forest Fire Service Patrol and Fire Suppression Unit, 1922.

ciation and six associations in western Oregon.

In Georgia, as in the far West, organized fire control was initiated by a number of private protective associations. They started in about 1924 but the effort was greatly stimulated in 1933 in order to qualify for the Civilian Conservation Corps camps and for the protective benefits from the CCC program.

Federal cooperation with the States in protecting forest lands from fire originated with the act of March 1, 1911, commonly known as the Weeks law. This law inaugurated a new and then untried national policy of cooperation with the States to control forest fires. The Federal Government had been protecting Federal forests, but about 80 percent of all forest land in the country was privately owned and was almost wholly unprotected. The major forest fire problem of the day centered in these areas.

Upon passage of the Weeks law, 11 of the 16 States then having forest fire protection programs promptly entered into agreements with the Federal Government to cooperate in the Forest Fire Control Program (table 1). The States which joined the program during the first year were: Connecticut, Maine, Maryland, Massachusetts, Minnesota, New Hampshire, New Jersey, New York, Oregon, Vermont, and Wisconsin. Each year thereafter, under the Weeks law, one or more new States were added to the list of cooperators, except in the years 1917 and 1923. In the last year of the Weeks law program (1925), the Federal Government was cooperating with 29 States which were protecting about 178 million acres.

TABLE 1.—*States cooperating with the Federal Government in forest fire control by years*

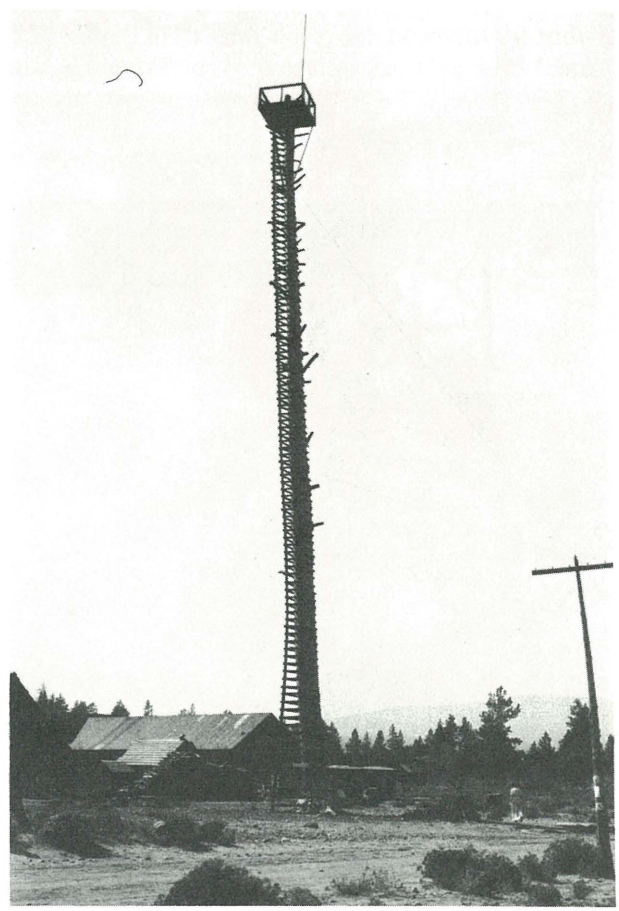
Year	*Total Number of States*	*Cooperating States*
1911	11	Connecticut, Maine, Maryland, Massachusetts, Minnesota, New Hampshire, New Jersey, New York, Oregon, Vermont, Wisconsin.
1912	12	Washington.
1913	17	Idaho, Kentucky, Montana, South Dakota, West Virginia.
1914	18	Michigan.
1915	20	North Carolina, Virginia.
1916	21	Texas.
1918	23	Louisiana, Rhode Island.
1919	24	California.
1920	24	Pennsylvania (Kentucky dropped out).
1921	25	Tennessee.
1922	26	Ohio.
1924	28	Alabama, New Mexico.
1925	29	Kentucky (came back in.)
1926	33	Georgia, Missouri, Mississippi, Oklahoma.
1927	34	Indiana.
1928	38	Illinois, South Carolina, Florida, Delaware.
1931	40	Nevada and Hawaii.
1932	38	(Illinois and Missouri dropped out.)
1933	39	Arkansas.
1938	41	(Illinois and Missouri came back in.)
1939	42	Colorado.
1941	43	Utah.
1946	44	Iowa.
1955	45	North Dakota.
1958	46	Nebraska.
1959	47	Wyoming.
1960	48	Alaska.
1962	49	Kansas.
1966	50	Arizona.

During the first 10 years under the Weeks law, the Federal funds were limited to detection only, to employ lookout observers and patrolmen. As the State fire-control operation expanded, it became apparent to both the Forest Service and the States that it would be necessary for the Federal Government to share in the complete State fire-control program. Accordingly, the policy was changed and each cooperating State was given a specific Federal allotment which it could use, on a reimbursement basis, for any legitimate fire protection obligation.

The Evolution of the Lookout Tower

Starting about 1900, the use of fixed lookout points originated and expanded. The earliest fixed-point lookouts were simply a platform mounted in a tree with slats nailed to the tree to facilitate climbing to the platform (fig. 8). This was followed by simple structures located on prominent peaks in the West and crude tree towers in the Eastern States. Initially these fixed lookout stations were used primarily by patrolmen as observation points on their routes, and were gradually converted into permanent lookout stations with telephone connections to the dispatcher's headquarters. The early lookout stations were usually constructed with locally available timber (fig. 9). The steel tower later came into use and, due to reasons of cost, simplicity of erection, and durability, has for the most part replaced all other types of towers. On many lookout sites where observation is not obscured by surrounding forest or terrain, the lookout is built on the ground; it may be two-storied with the lower portion used either for living quarters or storage (figs. 6 and 10).

The number of lookout towers used by the State Forestry Departments and the National Forests increased steadily until 1953 when they reached a peak of 5,060 towers. Since that time, there has been a steady decrease. The most recent count in 1967 indicates a decrease of about 30 percent since the peak year. Conversely, the number of aircraft used by the States has rapidly increased. In 1945 there were only four State-owned aircraft used for fire protection in the United States. In 1967 there were over 200 State-owned aircraft—one of the largest nonmilitary air fleets in the world. An equal or larger number of privately owned aircraft are hired for aerial observation under contract.



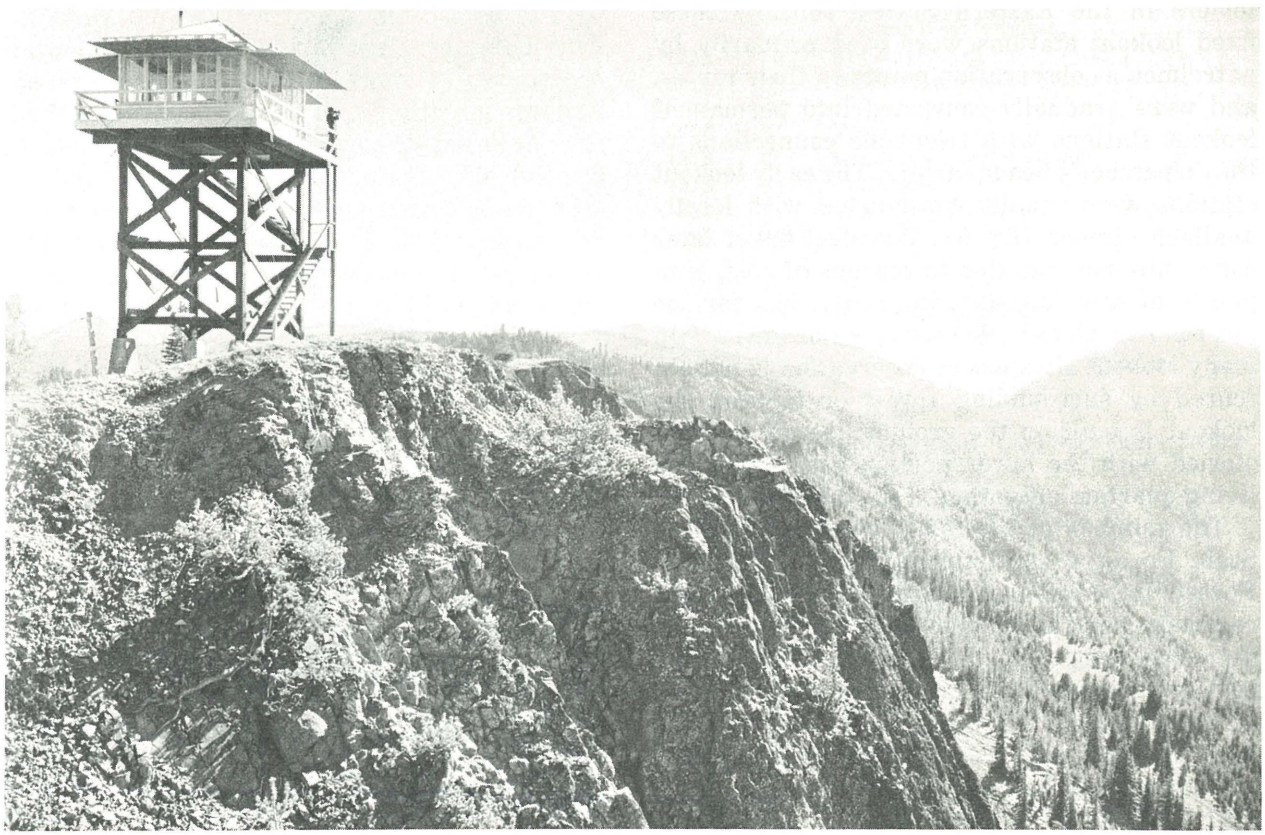
F–158847

Figure 8.—Sisters Lookout Tower, Oreg., 1921.

324-900 O—68——2

F—424122

Figure 9.—First "lady lookout" in the Olympics, Wash., 1920.

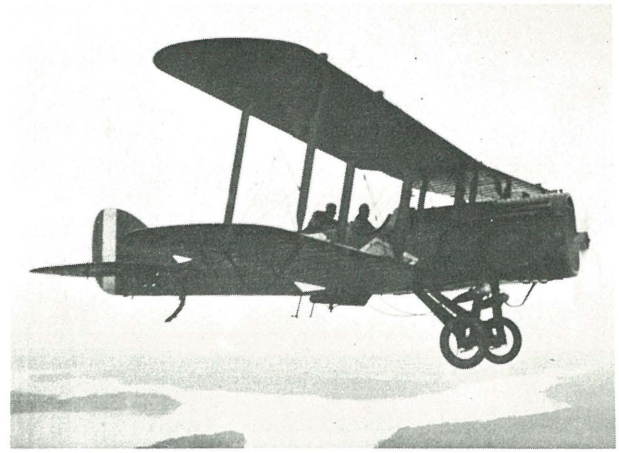


F—354941

Figure 10.—Little Bald Mountain Lookout, Wash., 1937.

The History of Aircraft Use for Fire Detection

The early use of aircraft for patrol is an interesting story. There are many who claimed to have first used aircraft for fire detection, but certainly one of the first uses was just after the end of World War I, when the U.S. D.A. Forest Service and the U.S. Army Air Corps combined their efforts to establish an aerial fire patrol in California in 1919. This civilian-military fire patrol was soon extended to include parts of Washington, Oregon, Idaho, and Montana (fig. 11). In 1925, the Forest Service organized a fire patrol flying out of Spokane, Wash. The initial uses of aircraft were purely supplemental to the lookout and ground patrol detection systems (fig. 12).



F–162658

Figure 11.—Forest patrol airplane, Olympic Air Patrol, Washington, 1921.

In each of the States a period of similar evolution in the wildland fire detection program has taken place. For understandable reasons, the type of detection varies considerably from State to State. In a few States, such as Michigan, and in some National Forests, such as the Superior National Forest in Minnesota, there has been an almost complete conversion to air-ground detection. In other States where conditions of accessibility, fire risk, and fire hazard are different, the change has not been as rapid. When we consider all States, however, there is a definite trend toward the increased use of aircraft for detection. This trend does not necessarily indicate a complete conversion to aircraft from lookout stations, however.

Figure 12.—The gondola of a pony blimp, ready for takeoff on fire patrol, California, 1921.

F–156937

CHAPTER II

CURRENT TRENDS IN FOREST FIRE DETECTION

With the development of highly efficient radios and modern aircraft, the overall forest fire detection dimension has changed considerably. Telephone lines from lookout towers to ranger stations are rapidly being dismantled to save the high maintenance cost involved. Many units have completely converted to radio communication and have developed a network which ties into commercial telephone communications. Recent studies of fire lookout effectiveness have resulted in the discontinuation of tower-manning at many stations. Frequently this has resulted in vandalism at lookout towers and service buildings and residences. This in turn has brought about the dismantling of lookout stations entirely at many points.

The Advancement of Aerial Detection

Modern aircraft offers an effective means of fire detection. Fire control personnel frequently indulge in heated arguments relative to air patrol versus ground detection. The uses of aircraft are primarily: (1) Detection of hitherto unreported smokes, (2) checking of such smokes, and (3) reconnaissance of going fires. Use of aircraft for reconnaissance has proved to be very effective. Aircraft are invaluable in checking smokes, in sizing up control problems, and in providing data to dispatchers. In some cases, aircraft are used in directing ground attack action. There is also considerable evidence that aerial reconnaissance is a deterrent to incendiarism.

Aircraft as a primary detector has been most successful in the detection of lightning fires which, in the United States, are most prevalent in the mountainous areas of the West.

During periods of low fire danger, the time tolerance is fairly long and operation of a tower system very expensive in relation to the likelihood of detecting wildfire. A few patrol flights may serve the needs in such situations.

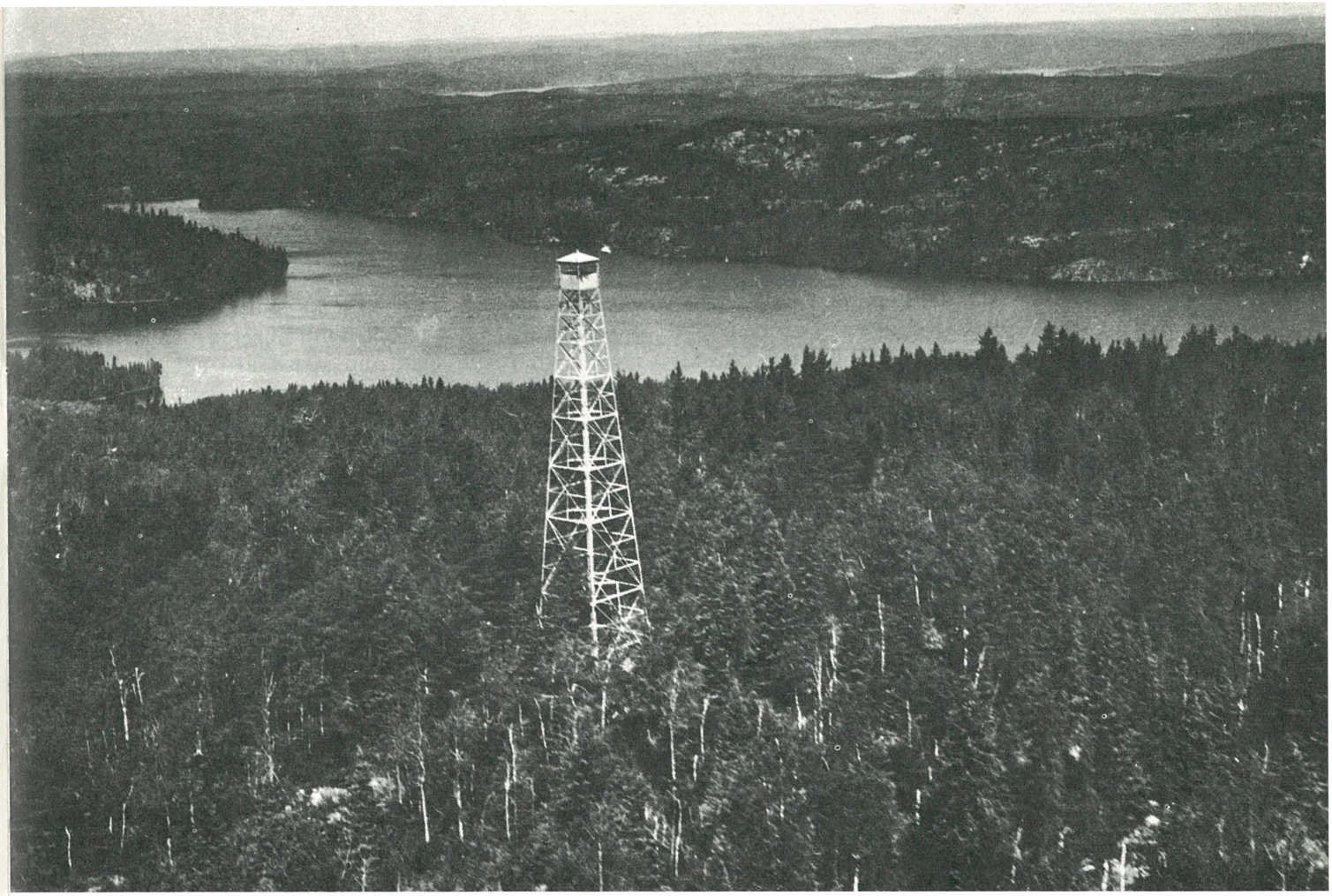
In Canada, there are vast areas of relatively low-value lands which must be protected. Here is an example of where a fixed point detection system is both difficult and exceedingly expensive to install and operate. Fire occurrence is relatively low and acceptable discovery tolerance is fairly long in most cases. Under such conditions, the Canadians have found the use of aircraft for p r i m a r y detection to be most economical.

Conversely, in many southern areas, aircraft have been correspondingly less successful and the economic advantage is less in relation to a fixed-point ground detection. This is true where discovery time tolerances are short, values-at-risk are high, man-caused fires predominate, and ground-detection systems are economical to operate.

Some Considerations of Aerial Detection

Within the limits of visibility, the width of the strip of forest lands seen and the proportion of total territory seen increase with the altitude of the aircraft. This is particularly true in a steep terrain. The feasible detection limits of increasing altitude, in addition to visibility itself, is the total area an observer can effectively view and the angle from which smokes are most visible.

It is true that aircraft detection has a short observation time for any particular spot and it is also true that there is a definite limit as to how much area a man can effectively scan in the brief time available. The observer must keep in mind that the angle of the view is important. In general, smokes are more easily seen in profile than at an oblique angle. The higher the plane, the more nearly the observer is looking directly



F—400723

Figure 13.—Lookout tower on Superior National Forest, 1940. Tower no longer manned. Only three lookout stations are now manned on the forest.

F—496543

Figure 15.—Model 47 G–2 helicopter in takeoff from helispot. Idaho, 1958.

F—446460

Figure 14.—Composite photo-radio communication between ground and blimp for fire control. California, 1943.

down on the smoke column, and the less of it he sees. In the case of small fires, this can make a significant difference in detection.

For the most part, patrol aircraft fly relatively low. The most common elevation is between 1,000 and 2,000 feet above terrain. The area under observation is generally a strip extending 5 to 10 miles on both sides of the observer's flight course. The route of patrol flying conditions and type of terrain will determine, to a large extent, the elevation in which the aircraft will fly within the described limitations.

Haze is less of a problem with aircraft than ground detection because the observer looks through less of it the more nearly he can look downward (fig. 17). When haze depth is low, as in many fairly level areas, aircraft detection may be effective when visibility from ground points is much restricted.

All things considered, fire detection from aircraft is highly efficient at the time of flight. Of course, there are exceptions. For reasons unexplained, there are occasions where smokes which apparently are fully visible are unseen by the observer.

The majority of aircraft used for fire detection are those which can be operated most economically, provide optimum observer visibility and where payload and speed are not an important factor. Commonly used aircraft are the Super Cub, Cessna 180 or 185, the Helio Courier, the Dornier Do–28, Centaur, Twin Beech, Beaver, Turbo-Beaver, and the Otter. The more powerful of these craft are also used for initial attack or to cool off a fire with water or retardant drops until reinforcements can arrive.

The Air-Ground Detection System

The trend of most fire protection organizations at this time is toward a combined aerial and fixed-point detection system (fig. 13). The most frequent point of discussion here, is whether the air detection should supplement or dominate the ground detection (figs. 14 and 15). Here again, the local situation is the guide to proper use of both aircraft and fixed-point stations. The objective is to exploit the strength and advantages of each to bring about the most effective forest fire detection possible in any particular area.

Efficient radio communication is essential to the successful operation of the air detection unit. Each patrol plane must be equipped with a suitable receiver and transmitter on the same frequency as used by the lookouts, dispatchers, patrol cars, and smokechasers. It is necessary to require that contract patrol planes be shielded or otherwise made suitable for the radio installation. Modern high-frequency (FM) sets are entirely suitable for the necessary two-way communication.

Radio repeaters are essential to insure communication over large areas. Use of repeaters eliminates need for ground personnel to monitor and relay reconnaissance flight messages. Without repeaters, 20 miles is considered the maximum effective distance from the aircraft to ground contacts.

Training of observers is extremely important in the air-ground detection system. They need to be thoroughly indoctrinated in the techniques of observing and also radio operations. Additional details on planning and operating the air-ground detection system are given in Chapter IV.

CHAPTER III

ADVANTAGES AND DISADVANTAGES OF SPECIFIC DETECTION SYSTEMS

The advantages and disadvantages of the three major types of detection now being used in the United States must be considered in the light of local conditions. Most fire-control experts agree that the most desirable detection system in any one area is dependent upon a number of local variables.

In considering the system to use in any particular unit, the fire chief, or planner, must take into account such factors as:

1. The inaccessibility of the area being protected.
2. The topography.
3. The prevalence of haze or air pollution which affects visibility at the lower levels.
4. The principal causes and locations of fire.
5. The prevalence of extremely high winds during the critical period.
6. The availability of trained observers and suitable aircraft for patrol.
7. The frequency of night fires.
8. The cost of each detection system.
9. The availability of accurate and detailed maps or aerial photographs.
10. The importance of the other uses of patrol aircraft for smokechasing and fire reconnaissance.

Lookout Towers

The principal advantages of the fixed station are: (1) The full-time coverage including night detection, (2) detection during periods of extremely high winds when aircraft are unable to fly, and (3) more stable and reliable radio communication in some cases.

The primary disadvantages are: (1) The excessive cost of towermanning which has increased substantially in recent years, (2) inadequate detection in blind areas (fig. 16), and (3) the lack of ability to obtain detailed information on the fire.

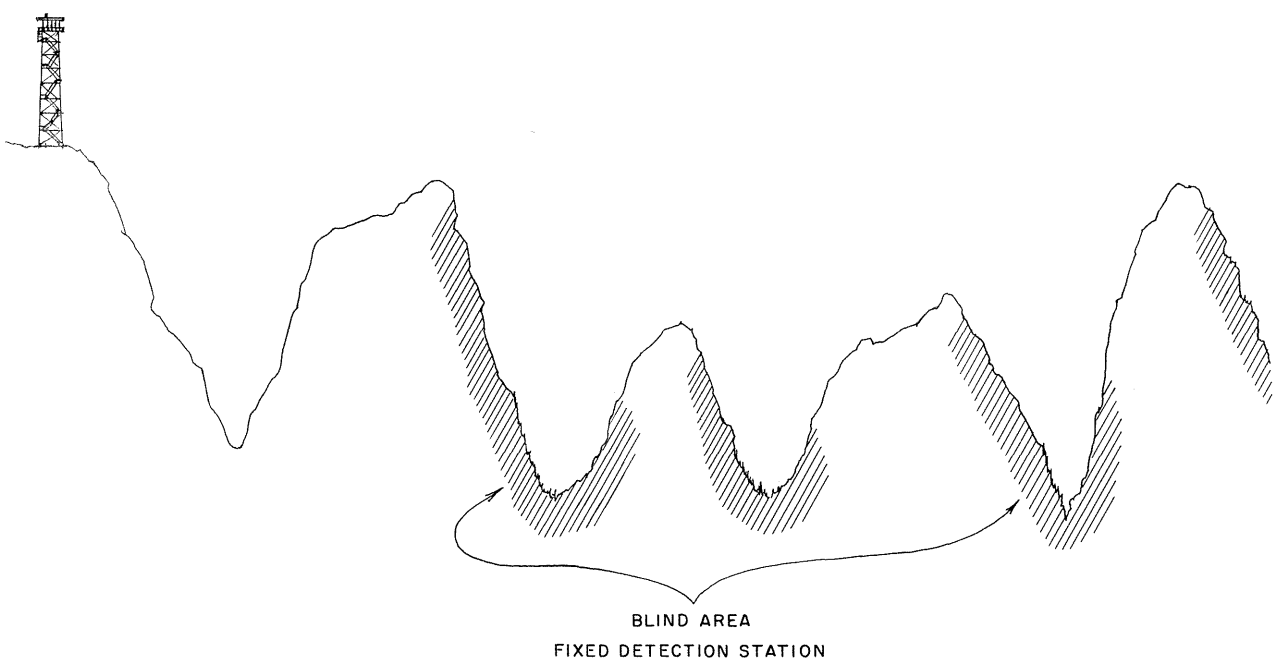


Figure 16.—Blind areas from fixed detection stations.

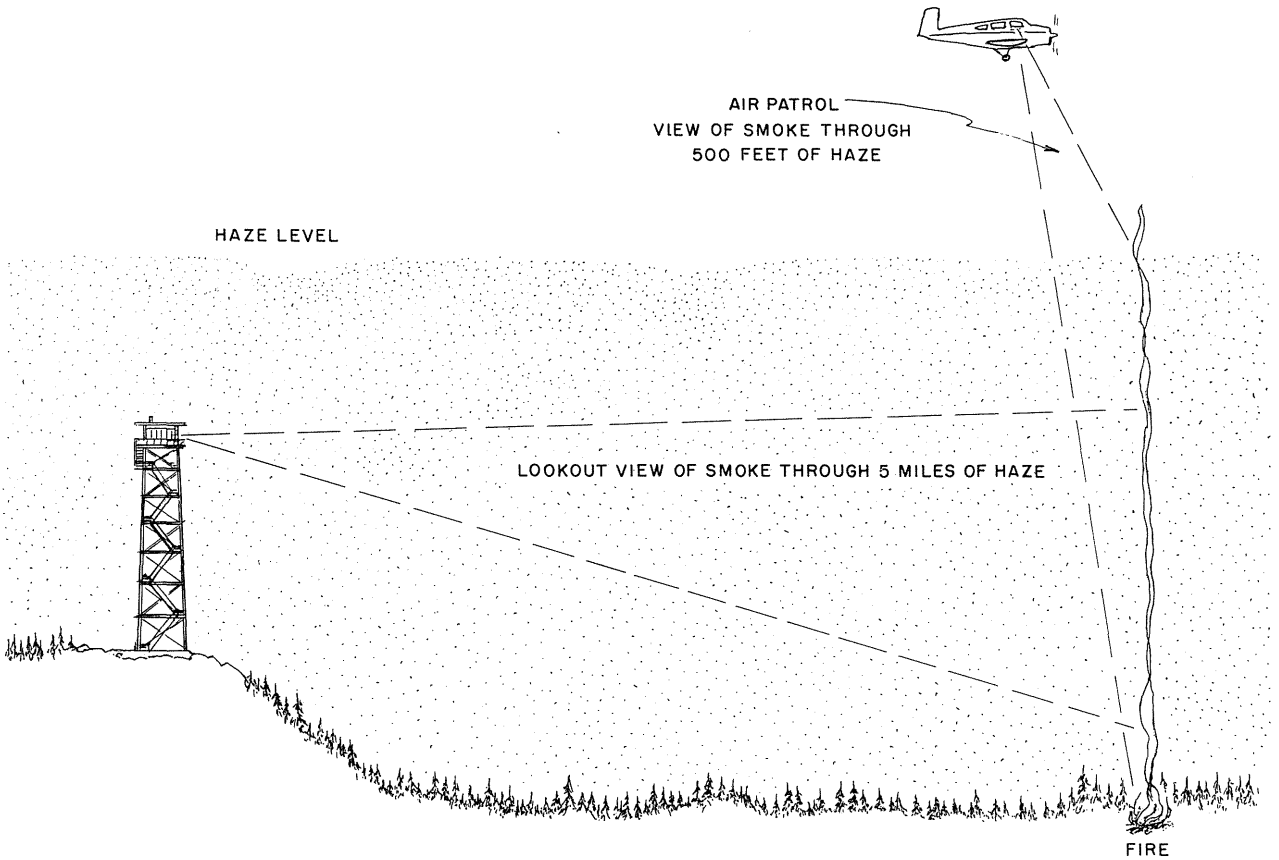


Figure 17.—Comparative haze problem: fixed detection station and air patrol.

Both these advantages and disadvantages can be tempered somewhat, however. Although, in theory, the towerman had full-time detection coverage, experience has repeatedly shown us that this is not necessarily true. Smokes which should have been readily visible to towermen have been reported by other means. Studies of fire reporting have indicated that some towers have been extremely ineffective overall. These studies reveal that *certain towers have not made a first report on a smoke over a period of years* (figs. 17, 18, and 19).

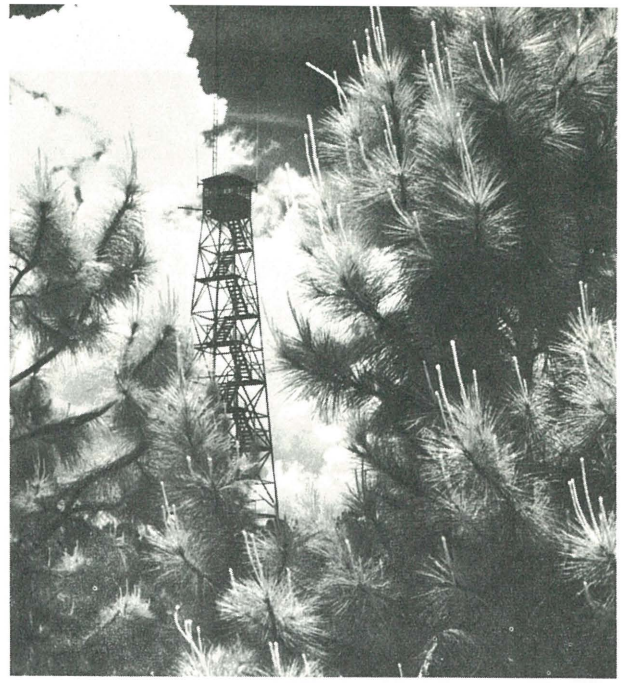
Towers can be manned at night but, here again, experience has shown that night manning of towers in many instances is not effective.

Air Patrol

Aircraft, in most areas, are efficient and economical in the area that can be seen per unit of time. No fixed-point system can compare with them on this count. Flexibility is a major advantage of aircraft. Any specific area can be fully seen; there need not be any consistent blind spots to aircraft. By varying the route, time, and elevation, aircraft can be efficient over a wider range of visibility conditions than ground detection. Aircraft also have the advantage of being able to circle and thoroughly scout a newly discovered smoke. In many cases they can prevent false runs by identifying controlled burning and fires which cannot spread. Fire patrol aircraft can be of much help in control operations by directing men along the safest and best

route to use in reaching the fire and also in advising fire-control crews of the best locations for line construction and backfiring (fig. 20).

The disadvantage of aerial detection is principally the lack of continuous observation. Studies have shown, however, that observation of critical areas at least once an hour is feasible in all but the very high rate-of-spread areas. Adverse flying conditions, such as extremely high winds or other atmospheric turbulence, can sharply limit the use of aircraft. Frequently these are also periods of extremely high fire hazard, which is an unfortunate combination of circumstances. Night flying is not considered safe enough at low levels to be used extensively at this time. However, with the increased number of well-lighted air fields and the growing possibilities for the use of airborne infrared systems, air patrol at night is being used more frequently.



F–383755

Figure 18.—Radio-equipped lookout tower, Florida Forest Service.

Air-Ground Detection

Air-ground detection has the advantages of both lookout and air patrol systems. It also reduces the disadvantages of both systems. Then too, it can be varied, dependent upon local conditions. In some areas it has been proven feasible to convert largely to air patrol leaving only a very few key lookout towers for communication and continuous observation. In other areas, dependence is primarily upon the tower system with only supplemental support provided by the air fleet.

In areas of mixed or adjacent protection jurisdiction, air patrol offers mutual advantages. Cooperative arrangements for air patrol are proving successful throughout the country. All indications point to future expansion of cooperative detection systems.

Air-ground detection also provides an opportunity for intensive patrol of exteremely high value areas. Those areas with heavy man-caused fire risk and "flashy" fuels require more fixed detectors than areas where fires are primarily lightning-caused in mountainous areas with comparatively short burning seasons. The lookout stations also provide weather information, supplement radio communication networks, and in some cases, provide smokechasing and ground patrol coverage.

The air-ground system permits great flexibility. Air patrol may be expanded or curtailed as required on short notice. During periods of low fire danger, flying hours are "banked" for use when needed.

To a large extent, this system eliminates the uneconomical manning of isolated towers and reduces the maintenance costs of towers and other structures. In recent years, vandalism has become an increasing problem at isolated tower locations. *These high labor costs and maintenance costs can be reduced by the use of the air-ground system.*

F–383755

Figure 19.—Towerman sighting smoke with alidade; Bake Butte tower, Arizona.

F–494904

Figure 20.—Beaver fire patrol plane, Superior National Forest, Minn.

CHAPTER IV

PLANNING A DETECTION SYSTEM

Basic Considerations

The basic aim in forest fire detection is to spot smokes promptly enough to permit control while they are small. Equal discovery time is not necessary for *all* fires. How quickly fires must be detected is dependent on suppression-force efficiency, fuels, and fire danger. Report and getaway elapsed times are usually short and relatively constant.

Discovery and travel time are consequently the key variables. Travel time, along with needed control forces, can be closely estimated once the location and size of the fire is known. Discovery of a fire is, in a sense, a creative act subject to no direct administrative preplanned control. Its fundamental importance rests on the fact that no suppression action can be taken until a fire is seen.

In practice, general detection-time standards are commonly established on an area basis in relation to average travel time requirements and the rate of spread and resistance to control of major fuel types.

In view of the fact that an area is seldom fully visible to observers at any given time, and because of the many human factors involved, it is extremely difficult to establish minimum discovery times. Detection of fire is not an exact science, though many would like to visualize it as such. It is also necessary to keep in mind that tolerable discovery time is also a variable, changing from area to area, season by season, and day to day. In some cases, to tolerable discovery time may change from hour to hour.

Although detection standards are used as general guides, modern detection systems are basically designed to find the fires as soon as possible in order to bring about effective suppression action, rather than to meet any fixed time standard. Commonly, the manning of lookout towers and the use of aircraft in detection are founded on taking calculated risks based on acceptance of probable discovery time (figs. 21 and 22).

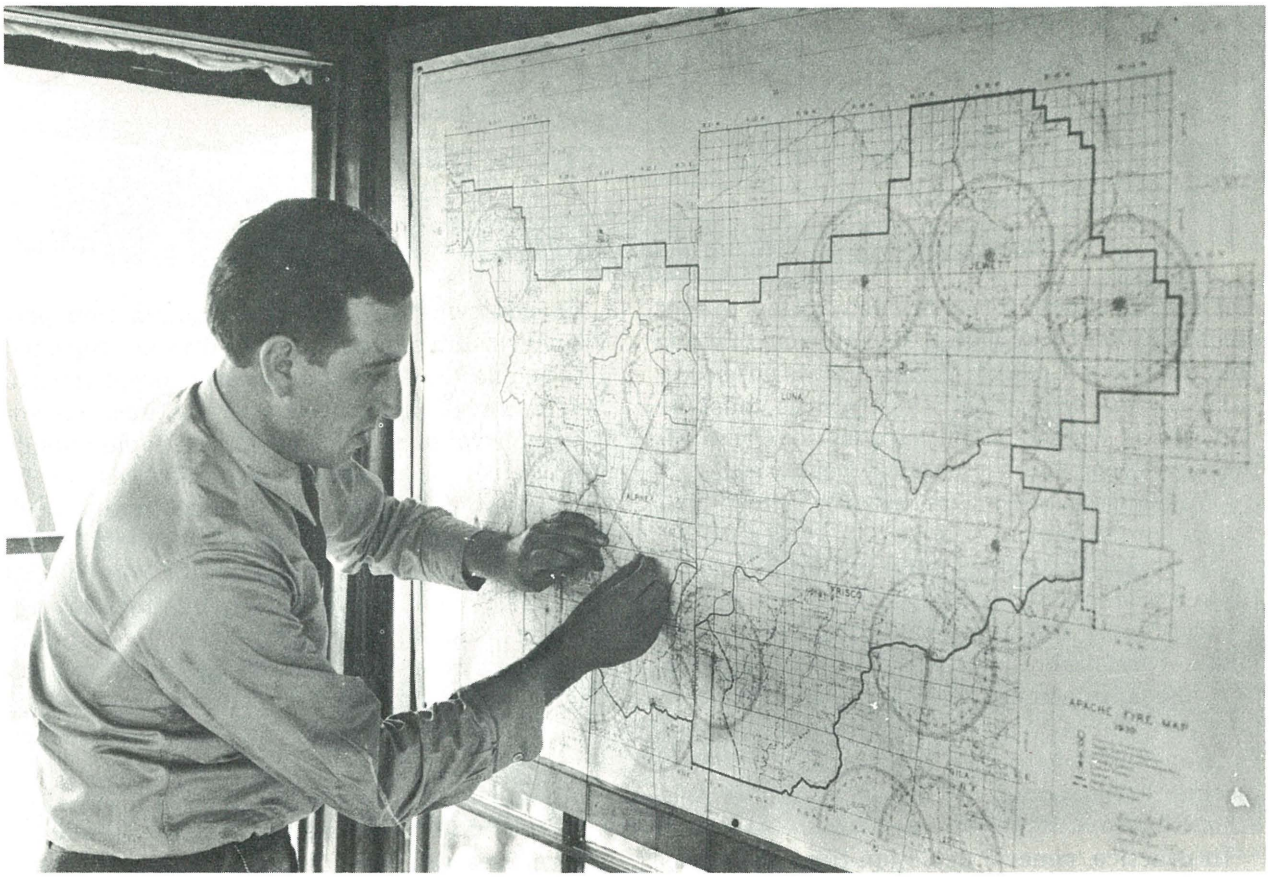
In addition to fire-control organization personnel used in detection, many fires are reported by people outside the control organization. While few, if any, control organizations rely entirely on voluntary detection by people outside the control organizations, such sources can be extremely important. There are many such sources, for instance, local residents, tourists, hunters, fishermen and private or commercial aviators. The effectiveness of volunteer fire reporting is mainly a direct consequence of preparatory fire prevention work. Volunteer reporting is particularly important during periods of low visibility when normal sources of detection are ineffective.

A basic consideration in planning a detection system is the identification of high risk areas where fires are most likely to occur or where dangers are potentially very high. Not all areas are equally dangerous and the detection problem is more complex than the need to see all areas equally.

Three major steps are involved in determination of these dangerous areas: *analysis of risk, hazard,* and *value.*

F–474427

Figure 21.—Zone dispatcher checking map with lady pilot previous to takeoff for air patrol.



F—383794

Figure 22.—Lookout dispatcher locating a fire by triangulation, Arizona, 1939.)

Analysis of risk centers on the facts of fire occurrence as given by past experience. Fire statistics may be broken down into the following categories: (1) Cause, (2) time of year, (3) time of day, (4) size of fire.

These data are tabulated and ordinarily presented on maps. Various techniques are employed to use this information most effectively. This information when recorded upon a map can be used to determine the high occurrence areas for both lightning and man-caused fires. Lightning follows an entirely different pattern of occurrence than man-caused fires.

The second step is an analysis of fuel hazards. This involves appraisal of fuels from the standpoint of potential rate of spread as well as resistance to and means of control. Areas of extreme hazard are given special consideration.

The third step is an appraisal of values that may be damaged by fire. Timber, recreation, water, wildlife habitat, and other forest values may be considered as well as property and esthetic values. *Consideration of these values is of the utmost importance.* A valuable recreational and summer-home area around a lake would be given special consideration to insure close detection coverage. The same might be true of an experimental forest, or stands of especially valuable timber, particularly if the risks were also considered to be high. If an area has an especially high recreational or watershed value, detection may be intensive if risk and hazard warrant.

Risk, hazard, and value information is utilized in determining specific areas of total danger and in general zoning of forest areas. The completeness of the information utilized, the detail of the analysis, and the specific procedures used will vary from State to State. No general formula can be provided. From a detection standpoint, the essential fact is that important areas be identified to the degree that adequate steps can be taken to detect fires in time to prevent intolerable losses.

Planning an Air-Ground Detection System

The northern region of the U.S.D.A. Forest Service has pioneered in the development of air-ground detection systems. The handbook which they have developed for air-ground detection is a handy working tool for any fire detection planner. Much of the information included in the following discussion is drawn from the work done by the northern region and the Northern Forest Fire Laboratory.

The first step in air-ground detection planning is to become familiar with all available maps, charts, seen-area composites, and written plans. Accurate mapping is the first step in setting up a detection plan for any area. Whenever possible, topographic base maps should be provided. If these are not available, reliance must be placed on the best maps that can be obtained.

Any detection plan must segregate and define the areas to be covered. Early fire planning treated all areas alike and did not differentiate between long or short season areas, or areas which because of value, occurrence, or fuels, constituted the most important area from a detection standpoint.

The organization for the combined air-ground detection unit remains essentially the same as the fixed-point system that has been most commonly used in the past. The major difference is the expanded use of aircraft and the reduction in the number of lookouts.

Calculation of flying costs for the average season is done by polling the hours of anticipated patrol indicated by costs per hour of flying time. There is no adequate mechanical means or formula for calculating the amount of patrol time required for the different danger classes. This must be left to experienced judgment, with consideration given to the amount of coverage required for detection in accordance with the need existing at the time.

One advantage of aerial detection is the fact that it costs little to have the patrol planes available for early or late season detection when fire dangers do not usually require fixed detectors or there are rapid shifts from low danger to high danger and back to low danger. Substantial savings may be made by reducing the period of occupancy of lookouts to a minimum. Planners should therefore carefully review fire danger and occurrence records and reappraise the periods of occupancy for the fixed detector group.

Despite years of study and research in the field of detection, we still have much to learn. The use of modern technology in fire detection continues to be a challenging field.

CHAPTER V

BUDGETING AND COST FACTORS

Economic justification of forest fire control (including detection) is essential because finances are not unlimited. Cost must be weighed against benefits received through reduced damage. It is the responsibility of the fire-control chief to determine and achieve a desirable balance.

In the early days of forest fire control in the United States, justification of fire control was not a problem. Without organized fire control, intolerable damage from wildfire was inevitable. Some type of control was obviously needed, and few people argued against this point.

As fire control has become more effective, and more costly, the point of diminishing returns is being approached in some situations. In most States of the Nation, as well as most Provinces of Canada, fire-control organizations have become both highly developed and expensive. The protection goals that were set a quarter of a century ago have been surpassed and are now considered inadequate. Forest resource values-at-risk from fire have increased tremendously. In general, these values-at-risk have increased more rapidly than the effectiveness of wildfire control.

As forest and related resources become more valuable and more diversified, their management also intensifies. Also, as recreation and other uses of the forest continue their spectacular increases, the ever-present threat of fire becomes more severe. Fuels build up in volume as a result of effective fire prevention and control efforts, to the point that hazards are substantially increased.

There is, therefore, a need to more closely examine the present and future protection needs and costs. Good fiscal management requires knowledge of costs as a prerequisite to any helpful economic analysis of fire-control needs. The fire-control officer cannot reasonably expect increased detection and control budgets without a clear showing of what is being achieved with present expenditures and what output is anticipated from increased funds.

Fire control usually must compete with other demands for money within a wildland management organization. Fire-control budgets must be considered along with entomological and pathological protection needs, and various land management activities such as timber production, utilization, recreation, wildlife, grazing, and soil and water conservation. Today, fire has to plead its case along with the needs of other resource management activities.

Forest fire detection accounts for a large part of the year-to-year expenditures in forest fire control. This is due to the high cost involved in salaries for lookouts, radio communications networks, construction and maintenance of lookout stations and telephone lines, and purchase or rental of aircraft. In recent years, there has been a growing realization that fire detection costs can be reduced substantially through the use of modern technology and equipment. As an example, the expensive and frequently ineffective telephone line systems connecting lookout towers and dispatchers are rapidly being disposed of. Radio communication is not only considered to be more reliable, but it is much less expensive than the maintenance of many miles of telephone line.

Many State forest fire divisions and the U.S. Department of Agriculture, Forest Service, are reducing their detection costs substantially through the increased use of patrol aircraft. The State of Michigan is an example. Before obtaining its first detection aircraft in 1959, Michigan was manning 150 towers each year. In 1967 this

CHAPTER V

BUDGETING AND COST FACTORS

Economic justification of forest fire control (including detection) is essential because finances are not unlimited. Cost must be weighed against benefits received through reduced damage. It is the responsibility of the fire-control chief to determine and achieve a desirable balance.

In the early days of forest fire control in the United States, justification of fire control was not a problem. Without organized fire control, intolerable damage from wildfire was inevitable. Some type of control was obviously needed, and few people argued against this point.

As fire control has become more effective, and more costly, the point of diminishing returns is being approached in some situations. In most States of the Nation, as well as most Provinces of Canada, fire-control organizations have become both highly developed and expensive. The protection goals that were set a quarter of a century ago have been surpassed and are now considered inadequate. Forest resource values-at-risk from fire have increased tremendously. In general, these values-at-risk have increased more rapidly than the effectiveness of wildfire control.

As forest and related resources become more valuable and more diversified, their management also intensifies. Also, as recreation and other uses of the forest continue their spectacular increases, the ever-present threat of fire becomes more severe. Fuels build up in volume as a result of effective fire prevention and control efforts, to the point that hazards are substantially increased.

There is, therefore, a need to more closely examine the present and future protection needs and costs. Good fiscal management requires knowledge of costs as a prerequisite to any helpful economic analysis of fire-control needs. The fire-control officer cannot reasonably expect increased detection and control budgets without a clear showing of what is being achieved with present expenditures and what output is anticipated from increased funds.

Fire control usually must compete with other demands for money within a wildland management organization. Fire-control budgets must be considered along with entomological and pathological protection needs, and various land management activities such as timber production, utilization, recreation, wildlife, grazing, and soil and water conservation. Today, fire has to plead its case along with the needs of other resource management activities.

Forest fire detection accounts for a large part of the year-to-year expenditures in forest fire control. This is due to the high cost involved in salaries for lookouts, radio communications networks, construction and maintenance of lookout stations and telephone lines, and purchase or rental of aircraft. In recent years, there has been a growing realization that fire detection costs can be reduced substantially through the use of modern technology and equipment. As an example, the expensive and frequently ineffective telephone line systems connecting lookout towers and dispatchers are rapidly being disposed of. Radio communication is not only considered to be more reliable, but it is much less expensive than the maintenance of many miles of telephone line.

Many State forest fire divisions and the U.S. Department of Agriculture, Forest Service, are reducing their detection costs substantially through the increased use of patrol aircraft. The State of Michigan is an example. Before obtaining its first detection aircraft in 1959, Michigan was manning 150 towers each year. In 1967 this

number had been reduced to 50 by the use of aircraft.

TABLE 2.—*Aerial detection cost, Michigan Department of Conservation, based on 1965 costs*

Towers only		
Lookout's salary and expense	$4,000	
Tower and road maintenance	100	
	4,100	
Total for 150 towers		$615,000
Aircraft and towers		
Lookout's salary and expense	$4,000	
Tower and road maintenance	100	
	4,100	
Total for 50 towers	$205,000	
Pilot's salary and expense $10,750		
Total for nine pilots	96,750	
Airplane maintenance and operation	14,624	$316,374
Net savings		$298,626

The above table from the State of Michigan indicates a lookout salary and expense at the 1965 rate of $4,000, which would project to $600,000 for 150 men. Tower and radio maintenance figured at a nominal $100 average would add $15,000 to the cost, for a grand total of $615,000 to operate the conventional tower system.

The cost of operating nine State-owned airplanes and 50 towers is considerably less than the old tower system. A pilot's salary and expense is approximately $10,750 each for a total of $96,750. The airplane operational expense for 1965 was $14,624 which included gasoline and oil, minor repairs, major overhauls, and all other maintenance costs. There is an additional amount of $205,000 for lookouts' salaries and expenses, and tower maintenance. The total cost of operations was then $316,374. The savings for the year of 1965 was $298,626. The State of Michigan expects to be able to further reduce the number of remaining lookout towers.

Before embarking on a program of aerial detection, it is necessary to consider the initial cost of aircraft as well as to decide which is the best type of aircraft to meet the particular needs. There are many types and models of aircraft in use. Michigan is using four Piper Pawnees, three Piper Super Cubs, and two T34Bs. The Pawnee is designed for spraying and crop dusting with no passenger space and an average cruising speed of 90 miles per hour. The Super Cub can carry one passenger and has an average cruising speed of 100 miles per hour. Both of these planes are capable of flying at extremely slow speeds and of landing or taking off in very short distances.

The U.S. Department of Agriculture, Forest Service, in Michigan now uses contract flying. In the fiscal year of 1964, on the Huron-Manistee National Forest, nine towers were in use at a cost of $17,180. By converting to contracted air detection at a cost of $14,120, a savings of $3,060 was realized. Other savings also were significant; such benefits as being able to check the exact location of smokes, determining the equipment and manpower needs prior to attack, describing the fire behavior to the fire boss, and directing firefighters to the fire by the best route. Records indicate that detection efficiency increased from 54 percent of all fires reported by towers to 57 percent reported by aircraft. The per-hour cost of contract flying averaged about $20 and standby time cost about $8 to $10. There is very little standby time as the aircraft are normally in the air according to fire danger ratings.

A study was conducted in southwest Washington in 1966. To make a direct comparison between an air detection system and a conventional lookout system, the plan followed was to run the two systems on an operational basis in the same area with one superimposed over the other. The fixed detection system was managed in the normal fashion throughout the districts involved. An aerial patrol administered independently of the district was flown over the lookouts. The two detection systems were on separate radio frequencies to avoid one taking advantage of the other's smoke reports. The study area contained about 2.5 million acres gross, approximately 1 million acres of which is paying for forest protection. Detection flights were made at high elevations using Cessna 175 or equal aircraft. Flight frequency varied from one 2-hour-flight per day to five 2-hour-flights per day depending on fire weather. The study period ran 6½ months from April 1 to October 15. Sixteen lookouts were manned in the study area.

Cost of test operation (1 year):

Lookouts (16):	
Salary	$18,000
Depreciation	5,120
Batteries	960
Supply source	720
Mileage	160
Propane	120
Total	25,080
Cost/acre	$.025
Cost/fire detected	$720
Air Detection:	
Photos	$331
Plane rental	6,987
Insurance	262
Observer time	1,200
	8,780
Cost/acre	$.0087
Cost/fire detected	$98

The Superior National Forest in Minnesota made a study of the aerial detection on that forest over a period of 3 years (1956–58). The study indicated that detection costs of fixed stations as compared to air-ground detection are approximately the same. However, in this study, building and tower maintenance were not taken into consideration in the fixed station cost, but airplane maintenance and repair were included in aircraft costs.

Advantages of air patrol over fixed stations were revealed in the study. Briefly, air patrol was found to be more flexible, required less communication equipment and provided the means of leading ground crews to fires in isolated areas. Air patrol made it possible for the observer to give a more detailed description of the fire to the dispatcher, prevented many costly false alarms, provided more satisfactory detection than lookout towers, and provided fast transportation for small crews to island fires in the lake area.

In 1965 the Shawnee National Forest in Illinois made a comparison between aerial detection and tower detection costs. This analysis revealed that a significant savings could be made by the use of air patrol. Conversion to aerial detection brought about an annual savings of $5,700.

The Shawnee also found that there were other savings effected by the substitution of aircraft for towers. The aircraft eliminated the need for checks of nonreportable fires by ground crews. They also found that discovery time was reduced, resulting in smaller fires and decreased suppression costs. As in Minnesota, they found that detection aircraft were able to direct ground crews to difficult-to-find fires.

TABLE 3.—*Total number of manned lookout towers in the United States, 1953–68*

Year	*States*	*National Forests*	*Total*
1953	3,230	1,830	5,060
1963	3,410	1,250	4,660
1968	2,730	960	3,690

The Canadian Province of Ontario has made a number of studies of detection systems. A 1962 study was made to assess the efficiency and economics of the existing system and recommend changes, if warranted. Ontario at one time had a very sophisticated network of strategically located fire towers as the backbone of its detection system. Since first using aircraft for detection in 1921, the Province has consistently increased its aerial patrol. There were a number of reasons for the study. The cost of tower materials, tower erection, and tower maintenance has risen sharply in recent years. Some lookout stations cost more than $10,000 to establish, including the cost of steel tower purchase, tower erection and the living facilities required for the towerman and his family. Capable men availale for tower duty have been extremely hard to obtain in recent years. In some instances Ontario found it was necessary to leave towers unmanned because of the labor shortage. In addition, they experienced steep increases in towerman's wages and in the cost of the communications equipment required for each tower.

Ontario found through its visible-area mapping program that a great many towers were poorly located and that many additional towers would be needed to fill in the area where no coverage existed at all. The fixed stations system of detection was found to be inflexible. Air patrol on the other hand can be fitted to the actual daily detection requirements.

A most important factor in these considerations is that the effectiveness of the fixed-point system depends on the capabilities of many unskilled individuals, whereas, with use of aircraft, two or three skilled pilots and observers can accomplish the same function.

Ontario viewed all of these considerations in terms of costs. Its studies have been aimed at the question: Can the job of fire detection be accomplished with the same or greater effectiveness for equal or less costs using aircraft principally as opposed to fixed-point tower lookouts?

For example, on the Temagami Division the costs of detection per square mile were $7.90 for tower detection and $3.59 for air patrol. The costs per acre were $.0123 for towers and $.0056 for air patrol.

Ontario has concluded that aircraft will play an increasing role in its forest fire detection. Future detection systems will consist of a few key fixed-point stations combined with regular air patrols—a completely integrated system.

Helicopters have been used for forest fire detection, but they are generally considered to be too slow and expensive for general use in air patrol. Currently, a Bell G4 or Hiller 12E cost approximately $150 per hour; a Bell 204 costs $600 per hour; and the Sikorsky S–61 costs at least $1,200 per hour.

In spite of the high cost of helicopter operations, the use of this aircraft for detection purposes, combined with other fire control uses, should not be ignored. California has found that helicopters serve a valuable purpose in water drops directly on the fire line.

A dual-purpose helicopter, which would both detect and make water drops on fires when they are very small, obviously has possibilities. Fire research and fire-control equipment development personnel are now seeking ways to use the helicopter more effectively for overall fire-control purposes.

CHAPTER VI

MODERN TECHNOLOGY IN FOREST FIRE DETECTION

An ideal forest fire detection system would detect fires the instant they start, day or night, under any condition of visibility. Attainment of such a system now appears to be well within the reach of modern space-age technology. The fire detection system that the fire-control supervisor dreams about would have these essential attributes related to the varied kinds of detection problems:

1. It would be able to detect and pinpoint the location of a fire the instant it started.
2. It would be as effectively operable in darkness as in daylight.
3. Likewise, it would be operable despite low visibility caused by smoke, fog, or dense timber cover.
4. It would be reliable, safe, and inexpensive.

The primary consideration for any fire-control operation is (1) The size of the fire, and (2) its potential for causing damage at the time of initial attack. This depends upon type and continuity of fuel, rate of spread, and time elapsed from ignition to initial attack.

Under some circumstances, instant detection might be desirable, but not critical. The value of the area under protection would certainly influence the tolerability of delay; so would weather and fuel conditions at the point of ignition. If a longer interval between ignition and detection is tolerable, intermittent surveillance would be acceptable and an airborne system could be used. In some cases this delay would not be tolerable; then a fixed-location continuous lookout is required. Probably there will always be need for some fixed lookout stations. However, in many situations some delay would be tolerable, and the inherent advantages of intermittent surveillance could be exploited.

Hence, the first major question to be answered in a detection analysis must be: Does the particular area under study require continuous or only intermittent surveillance?

A second attribute of an ideal system is equal operability by day and night. Fires usually spread more slowly during nighttime hours, and quite often they could justifiably be ignored until daylight permitted detection by visible means. Ability to detect fire during the hours of darkness, however, would permit suppression forces to attack them at a time when control is much easier to achieve. Visual systems, such as manned lookouts, routine aerial patrols, and television, require daylight for their operation. Infrared, microwave, or active optical systems work satisfactorily in either daylight or darkness, but infrared functions better in darkness. The question here is: How urgently is a nighttime capability needed?

Another attribute of an ideal system is operability under any condition of visibility. On many days during the fire season, the atmosphere is clear and smoke can be detected by various means. There are, however, many days when visibility is obscured by smoke and haze; and these days are frequently the most dangerous.

When there is no smoke haze, no smog, nor cloud cover, detection of small smoke columns above a fire is relatively easy (fig. 23). However, when the atmosphere is cluttered with smog or smoke, such detection becomes extremely difficult either by the visual system or by other systems. Thus we see that any attempt to develop systems capable of operating under all atmospheric conditions is doomed to failure if it relies upon the detection of smoke. Fortunately, there is great promise in technological developments. New devices have been developed which rely upon energy radiated directly from the fire.

Instant detection cannot always be achieved from fixed locations. In many cases, fires may burn for extended periods before enough smoke rises to permit detection. A detection system scanning intermittently to detect the primary heat source may deduct a fire before a continuous surveillance system could detect a smoke column.

F—398976

Figure 23.—Aerial view of Elk Mountain fire, California.

FIRE DETECTION EXPERIMENTS
DENSE SPRUCE STAND

AERIAL PHOTO

INFRARED IMAGE

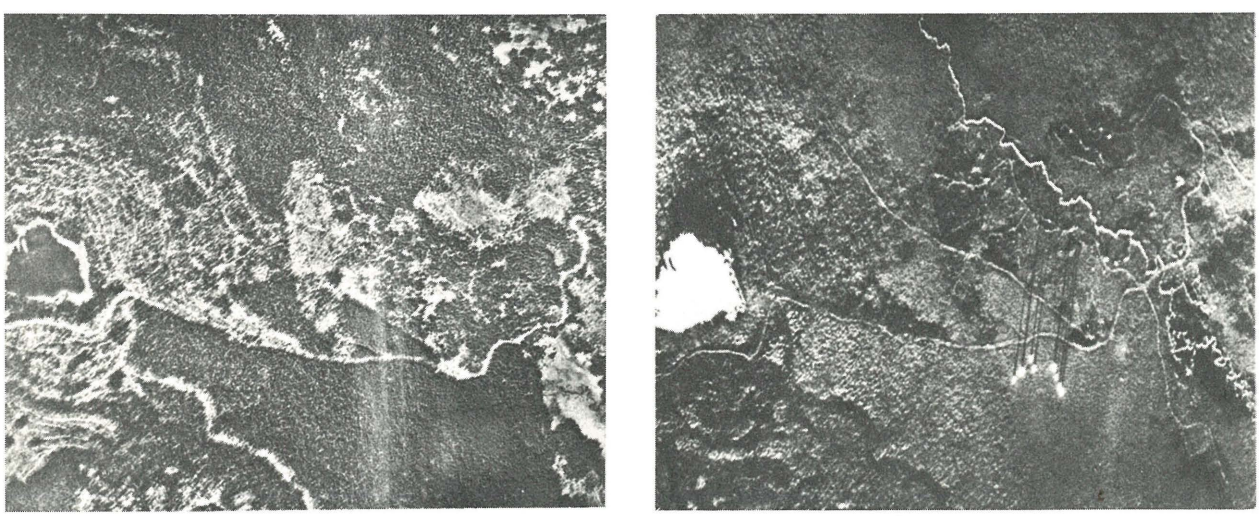


Figure 24.—A comparison of an aerial photo and an infrared image of the same area.

The manned lookout station depends upon visual detection of a rising column of smoke above a fire. If we are limited to using visual systems—either manned, television, or a combination of both—we are limited to daylight operation unless we provide some active source of illumination. Optical radars employing lasers for illumination may usefully supplement manned lookouts by providing a capability for detecting small smoke columns at night, and by providing a very high accuracy in range and air current for smokes detected during either day or night.

A television system installed at a lookout tower could do approximately what the human lookout can do, but it appears to add very little in terms of capability and does present some problems of a psychological nature as related to the viewer of the television screen. Conceivably, however, in some situations, a lookout equipped with a television system could reduce costs enough to be justified.

In situations where delays between ignition and detection can be tolerated, the detection system can be placed in aircraft to obtain a direct measure of the primary heat source. These are situations where modern electronic technology can be best applied. Fires radiate large amounts of energy in portions of the electromagnetic spectrum where the human eye has no sensitivity. Both infrared and microwave devices are sensitive to these portions of the spectrum and can be applied effectively to detect small fires both in daytime and at night. Both types of devices can detect small fires when smoke or smog makes it impossible to use visual systems.

The current research in fire detection at the Northern Forest Fire Laboratory of the Forest Service under Project Fire Scan has been directed toward implementing airborne infrared systems. Although microwave radiometry has the potential for operation under conditions of complete cloud cover, and infrared does not, the current state of technology dictates the choice of infrared in spite of this one major drawback.

Any practical airborne surveillance system must be capable of covering at least 5 miles to either side of the aircraft. Coverage is determined by the altitude and scan angle used. Data accumulated during recent years indicates that timber obscuration becomes a limiting factor beyond 60 degrees from the vertical. Because of this angular limitation, an operational altitude of 15,000 ft. above terrain is required to achieve 10 miles coverage. If the frequency of cloud cover below this altitude is too great, infrared techniques must be abandoned in favor of microwave.

The studies conducted by Project Fire Scan show great promise for improving detection capabilities where intermittent surveillance can be tolerated. If continuous surveillance is not required, then present infrared technology may achieve a detection capability during both daylight and nighttime hours and under conditions where smoke and smog eliminate conventional techniques (fig. 24). In short, the dreams of fire control officers may come to pass before many more years of development and testing are required.

BIBLIOGRAPHY

This bibliography has been prepared to provide the reader with a list of the types of references available dealing with forest fire detection. It is not considered an exhaustive bibliography, but rather a selective one, covering the more important factors involved.

Ainslie, Brian M., "Aircraft Detection vs. Tower Detection Cost Factor." Michigan Department of Conservation, 1967.

Air-Ground Detection Handbook, Region 1, Forest Service, U.S. Department of Agriculture, 1966.

Bjornsen, Robert L., "Infrared—A New Approach to Wildfire Mapping"—Fire Control Notes, Vol. 26, No. 3, Forest Service, U.S. Department of Agriculture, 1965.

Dieterich, John H., "Fire Detection Systems in the United States," Forest Service, U.S. Department of Agriculture, 1967.

Harris, Herbert K., "Training Guide, Aerial Observer Training," Forest Service, U.S. Department of Agriculture, 1955.

Harris, Herbert K., "Planning, Developing and Operating a Combination Air-Ground Detection System," Forest Service, U.S. Department of Agriculture, 1954.

Goodman, John F., "An Analysis of the Results of the Aerial Detection Projects, Temagami Kenora Areas," Ontario Department of Lands and Waters, 1966.

Gould, D. G., "Aerial Forest Fire Control," National Research Council, Canada, 1967.

Hirsch, Stanley N., "Possible Application of Electronic Devices to Forest Fire Detection," Research Note No. 91, Intermountain Forest and Range Exp. Sta., Forest Service, U.S. Department of Agriculture, 1962.

Hirsch, Stanley N., "Forest Fire Detection Systems," Forest Service, U.S. Department of Agriculture, 1964.

Hirsch, Stanley N., "Infrared Line Scanners—A Tool for Remote Sensing of Forested Areas," Forest Service, U.S. Department of Agriculture, 1965.

Hirsch, Stanley N., "Airborne Infrared Mapping of Forest Fires," Fire Technology, Vol. 1, No. 4, 1965.

Jay, James W., "Electronic Systems for Fire Detection—Infrared Mapping," Forest Service, U.S. Department of Agriculture, 1967.

Pinchot, Gifford, "The Progress of Forestry in the United States," Bureau of Forestry, U.S. Department of Agriculture, 1898.

Skill, Neil T., "The Use of Helicopters in Fire Control," Oregon State Forestry Department, 1968.

Such, Steve, "The Use of Aircraft for Smoke Detection in Michgan," Michigan Department of Conservation, 1967.

Swager, W. L., Fetterman, L. G. and Jenkins, F. M., "A Study of the Cooperative Forest Fire Control Problem," Battelle Memorial Institute, 1958.

Wilson, Ralph H., "The Remote Surveillance of Forest Fires," Applied Optics. Vol. 5, 1966.

Wilson, Ralph H. and Noste, Nonan V., "Project Fire Scan, Fire Detection Interim Report"—Research Paper Int–25, Forest Service, U.S. Department of Agriculture, 1966.

U.S. GOVERNMENT PRINTING OFFICE: 1968 O—324–900